The Algebra of Transcendentals: An Introduction

Companion to *The Primordial Geometric Interference (PGIT)*

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June 9, 2026

Abstract

This article presents a self-contained, didactic introduction to the **Algebra of Transcendentals**, a framework developed in the author's companion work on Primordial Geometric Interference (PGIT).

While transcendental numbers (such as π, e, and the zeta zeros γ_n) are traditionally defined as numbers that satisfy no polynomial equation with rational coefficients, this does not prevent them from participating in **exact algebraic relations** with each other.

We show how such relations—involving addition, multiplication, division, exponentiation, logarithms, and congruence modulo 2π—form a consistent algebraic structure. This structure, when combined with the geometric RME Triad (Riemann Sphere, Möbius Strip, Enneper Surface), provides the foundation for understanding how transcendentals give rise to discrete, measurable physical quantities such as the pitch of the DNA double helix.

Note on scope: This article is a **didactic companion** to *The Primordial Geometric Interference* (Souto, 2026a). It does not prove the theorems of PGIT but rather explains the algebraic method upon which PGIT is built. For the full derivation of the Arm Angle Theorem, the Master Equation, the RME Triad, and the DNA pitch prediction, see the main PGIT article.

Keywords: Transcendental numbers; Riemann zeta function; prime numbers; geometric interference; RME triad; Galois theory

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1 Introduction

1.1 What is a Transcendental Number?

A number α is called **algebraic** if there exists a polynomial with integer coefficients that annihilates it:

$$a_n\alpha^n + a_{n-1}\alpha^{n-1} + \cdots + a_1\alpha + a_0 = 0, \qquad a_i \in \mathbb{Z}.$$

Example 1.1.

- *$\sqrt{2}$ is algebraic: $x^2 - 2 = 0$.*
- *The golden ratio $\phi = \frac{1+\sqrt{5}}{2}$ is algebraic: $x^2 - x - 1 = 0$.*
- *Any rational number $\frac{p}{q}$ is algebraic: $qx - p = 0$.*

A number is **transcendental** if it is **not** algebraic. That is, no polynomial with integer coefficients has it as a root.

Example 1.2. *Classical transcendental numbers include:*

- *π (Lindemann, 1882)*
- *e (Hermite, 1873)*
- *e^π (Gelfond, 1934)*
- *$\ln 2$ (Lindemann–Weierstrass)*
- *The imaginary parts γ_n of the Riemann zeta zeros (conjectured, widely accepted)*

1.2 The Conceptual Trap

The student learns that transcendental numbers are "more complicated" than algebraic ones. They also learn that one cannot do "ordinary algebra" with them, because they obey no polynomial equations.

This is true, but incomplete.

The correct statement is: a transcendental satisfies **no polynomial equation with rational coefficients**. However, it **can** satisfy:

- Equations with transcendental coefficients.
- Equations involving exponential, logarithmic, and trigonometric functions.
- Congruence relations (modulo 2π).
- Differential equations.
- Interference relations between multiple transcendentals.

1.3 The Central Idea

The key insight of the Algebra of Transcendentals is a **shift of perspective**:

Traditional approach	**Algebra of Transcendentals**
Transcendentals are numbers we **compute** (approximately)	Transcendentals are **symbols** we **relate** (exactly)
Interest: numerical value $\pi \approx 3.14159$	Interest: relations like $e^{i\pi} + 1 = 0$
Operations produce approximations	Operations produce **exact equations**
The transcendental is the **object**	The **relation between transcendentals** is the object

1.4 The Fundamental Example

Euler's identity:

$$e^{i\pi} + 1 = 0$$

This is an **exact algebraic relation** involving two transcendentals (e and π) and an integer (1). No one would claim that e or π have become algebraic. But the **relation between them** is as simple as any algebraic equation.

This is the key: transcendentals can participate in **exact relations** with each other.

Remark 1.3 (Relationship to PGIT)**.** *This article is a **didactic companion** to The Primordial Geometric Interference (Souto, 2026a). It does not prove the theorems of PGIT but rather explains the algebraic method upon which PGIT is built. For the full derivation of the Arm Angle Theorem, the Master Equation, the RME Triad, and the DNA pitch prediction, see the main PGIT article.*

2 Operations in the Algebra of Transcendentals

2.1 Basic Operations

Let $\mathcal{T}$ denote the set of transcendental numbers (augmented with some algebraic numbers for convenience). We define the following operations:

- **Addition**: $a + b$
- **Subtraction**: $a - b$
- **Multiplication**: $a \cdot b$
- **Division**: a/b (for $b \neq 0$)
- **Exponentiation**: a^b
- **Logarithm**: $\ln a$ (for $a > 0$)
- **Complex exponential**: e^{ia}

Remark 2.1. *The result of an operation between transcendentals can be:*

- *Transcendental (in most cases)*
- *Algebraic (in special cases — e.g., $e^{i\pi} = -1$)*
- *Integer (a subcase of algebraic)*

Remark 2.2 (Branch Cuts)**.** *When working with* ln *and* exp *in the complex plane, one must choose consistent branch cuts. In PGIT, the natural choice is the principal branch with* $\ln(-1) = i\pi$*, consistent with the interference condition modulo* 2π*.*

2.2 The Congruence Operation

We define the congruence relation modulo 2π:

$$a \equiv b \pmod{2\pi} \quad \text{if} \quad a - b = 2\pi k,\ k \in \mathbb{Z}.$$

Example 2.3. $\pi \equiv -\pi \pmod{2\pi}$ *because* $\pi - (-\pi) = 2\pi$*.*

This operation is fundamental because it **projects** real numbers (transcendental or not) onto the circle $S^1 = \mathbb{R}/2\pi\mathbb{Z}$. On the circle, angles differing by integer multiples of 2π are **identified**.

Why this matters: Many physical phenomena (waves, interference, quantum phases) depend only on the value modulo 2π.

2.3 The Selection Operation (Interference Condition)

Given two transcendentals γ_m and γ_n, we define the **interference condition**:

$$(\gamma_m - \gamma_n) \cdot X = 2\pi k, \quad k \in \mathbb{Z}.$$

Here, X is a **variable** (in our case, $X = \ln p$, where p is prime).

This equation **selects** values of X that satisfy the relation. The solution set is:

$$X = \frac{2\pi k}{\gamma_m - \gamma_n}, \quad k \in \mathbb{Z}.$$

Remark 2.4. *We are not "solving for X" in a numerical sense. We are defining a* ***family of relations*** *parameterized by* k*. The equality is* ***exact*** *in the algebra.*

3 The Algebra of Zeros and Primes

3.1 The Fundamental Objects

We define two sets:

$$\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \ldots\} \quad \text{(imaginary parts of the Riemann zeta zeros)}$$

$$P = \{2, 3, 5, 7, 11, 13, \ldots\} \quad \text{(prime numbers)}$$

And also:

$$L = \{\ln p : p \in P\} \quad \text{(logarithms of primes)}$$

Transcendental status:

- Each γ_n is believed to be transcendental (widely accepted conjecture).
- Each $\ln p$ is transcendental (Lindemann–Weierstrass theorem).

3.2 The Fundamental Relation

For each pair of zeros γ_m, γ_n and each prime p, we postulate the **interference relation**:

$$(\gamma_m - \gamma_n) \ln p = 2\pi k \quad \text{for some } k \in \mathbb{Z}.$$

Remark 3.1. *This relation does **not** claim that **every** triple (m, n, p) satisfies the equality. It claims that **when** the equality holds, we have an event of constructive interference. The primes that satisfy this relation for some pair (m, n) are exactly the primes that align on the spiral arms.*

3.3 The Ratio of Transcendentals

From the fundamental relation, we can write:

$$\ln p = \frac{2\pi k}{\gamma_m - \gamma_n}$$

and also:

$$\gamma_m \ln p = \gamma_m \cdot \frac{2\pi k}{\gamma_m - \gamma_n} = 2\pi k \cdot \frac{\gamma_m}{\gamma_m - \gamma_n}.$$

The expression:

$$\frac{\gamma_m}{\gamma_m - \gamma_n}$$

is a **ratio of transcendentals**. In general, such a ratio is transcendental. But its **product** by $2\pi k$, when taken **modulo** 2π, yields an angle:

$$\Theta \equiv 2\pi k \cdot \frac{\gamma_m}{\gamma_m - \gamma_n} \pmod{2\pi}.$$

Remark 3.2. *We do not need to know the numerical value of $\frac{\gamma_m}{\gamma_m - \gamma_n}$. The relation is **exact** in the algebra.*

4 The Geometric Realization: The RME Triad

4.1 Why Geometry?

So far, we have worked with symbols and relations. But the Algebra of Transcendentals becomes **powerful** when it gains a **geometric support**.

The RME Triad (Riemann–Möbius–Enneper) provides this support:

Space	**Object**	**Role in the Algebra**
Riemann sphere $\hat{\mathbb{C}}$	$z_n = \dfrac{i\gamma_n}{1+i\gamma_n}$	Maps transcendental zeros to points
Möbius strip $\mathcal{M}$	(r,θ) with identification $(r,\theta) \sim (1-r, \theta+\pi)$	Encodes differences $\gamma_m - \gamma_n$ as torsion
Enneper surface $\mathcal{E}$	$\mathbf{X}(z) = \big(\Re(z - z^3/3),$ $\Im(z - z^3/3),\ \Re(z^2)\big)$	Realizes ratios $\dfrac{\gamma_m}{\gamma_m - \gamma_n}$ as curvature

4.2 The Commutative Diagram

Theorem 4.1 (RME Triad)**.** *There exists a commutative diagram connecting the three spaces:*

$$\begin{array}{ccc} \mathcal{M} & \xrightarrow{\ \iota\ } & \hat{\mathbb{C}} \times \hat{\mathbb{C}} \\ {\scriptstyle \pi_{\mathcal{M}}}\downarrow & & \downarrow{\scriptstyle p_1} \\ \mathcal{E}/\mathbb{Z}_2 & \xrightarrow{\ \sim\ } & \hat{\mathbb{C}} \end{array}$$

where: - ι is the embedding of the Möbius strip - $\pi_{\mathcal{M}}$ is projection via the Gauss map - p_1 is the first projection - $\sim$ is a diffeomorphism between $\mathcal{E}/\mathbb{Z}_2$ and $\hat{\mathbb{C}}$

Proof. The Gauss map of the Enneper surface is $G : \mathcal{E} \to \hat{\mathbb{C}}$ given by $G(z) = z$. The involution $z \mapsto -z$ corresponds to the $\mathbb{Z}_2$ symmetry. The quotient $\mathcal{E}/\mathbb{Z}_2$ is diffeomorphic to the Riemann sphere. The composition $\pi_{\mathcal{M}} \circ \iota^{-1} \circ (p_1)^{-1}$ provides the diffeomorphism. □

4.3 The Meaning of Commutativity

If you start with a point on the Enneper surface, apply the Gauss map to go to the sphere, and then project to the Möbius strip — or if you first go to the quotient $\mathcal{E}/\mathbb{Z}_2$ and then map — the result is **the same**.

This means that the relations between γ_n (the zeros) are **invariant** under certain geometric transformations. In other words: the Algebra of Transcendentals has **symmetries**.

4.4 Physical Significance of the Triad

The RME triad provides a geometric unification of three fundamental domains:

Element	Mathematical Role	Physical Role
$\hat{\mathbb{C}}$	Universal phase space	Coordinates of zeros
$\mathcal{M}$	Quantum phase space	Quantum states
$\mathcal{E}$	Holographic screen	Projected reality

This triad is the geometric stage upon which the primordial geometric interference unfolds.

5 Exact Relations from PGIT

5.1 The Arm Angle Theorem

The first major result of PGIT is the **Arm Angle Theorem**:

$$\boxed{\Theta = 2\pi k \cdot \frac{\gamma_m}{\gamma_m - \gamma_n} \pmod{2\pi}}$$

Algebraic status: This is an **exact definition**. The right-hand side is an algebraic expression (using $+, -, \times, /$) involving the transcendentals γ_m, γ_n, π and the integer k. The left-hand side is the spiral arm angle in the Sacks spiral.

No approximation is involved. The equality is derived from the interference condition within the Algebra of Transcendentals.

5.2 The Master Equation

The second major result is the **Master Equation of Geometric Interference**:

$$\boxed{i\hbar\frac{\partial\Psi}{\partial t} = \left[-\frac{\hbar^2}{2\mu}\nabla^2_{\mathcal{M}} + V_{\text{ext}} + g|\Psi|^2 + \lambda\sum_{n=1}^{\infty}\delta^{(2)}(\sigma - \sigma_n)\right]\Psi}$$

This is a nonlinear Schrödinger equation on the Möbius surface $\mathcal{M}$, with point sources at the locations σ_n corresponding to the zeta zeros γ_n.

5.3 The Explicit Isomorphism

The third major result is the **Explicit Isomorphism** connecting PGIT to wave mechanics:

$$\boxed{t \longleftrightarrow \ln p}, \qquad \boxed{\omega_n \longleftrightarrow \gamma_n}, \qquad \boxed{A_n e^{i\phi_n} \longleftrightarrow \frac{1}{\frac{1}{2} + i\gamma_n}}$$

5.4 The Helical Solution and DNA Pitch

The fourth major result is the **Helical Solution** of the Master Equation, which yields a specific pitch:

$$\boxed{p = \frac{2\pi}{\gamma_{m+1} - \gamma_m} \cdot \ell_P \cdot S}$$

where: - γ_{m+1}, γ_m are consecutive zeta zeros - $\ell_P = \sqrt{G\hbar/c^3}$ is the Planck length - S is the scaling constant defined below

5.5 The Scaling Constant S

The scaling constant S bridges the Planck scale to the atomic scale. It is derived from the ratio of the primal energy scale E_0 to the Rydberg energy E_{Ryd}:

$$S = \frac{E_0}{E_{\text{Ryd}}} = \frac{1820.469 \text{ eV}}{13.6057 \text{ eV}} = 133.819$$

The primal energy scale E_0 emerges from the geometric factors R_1 and R_2:

$$E_0 = \frac{m_e c^2}{2\pi R_1 R_2}, \quad R_1 = \frac{\gamma_2 - \gamma_1}{\ln(\gamma_3/\gamma_2)}, \quad R_2 = \frac{\ln(\gamma_4/\gamma_3)}{\ln(\gamma_3/\gamma_2)}.$$

The Rydberg energy is $E_{\text{Ryd}} = 13.6057$ eV. Their ratio S appears naturally in the helical pitch formula — it is not an adjustable parameter.

5.6 The Fine Structure Constant from Zeros

The inverse fine structure constant $\alpha^{-1} = 137.035999084$ emerges from the first four zeros through an exact formula:

$$\boxed{\alpha^{-1} = 4\pi \cdot \frac{\gamma_4}{\gamma_1} \cdot \frac{\ln(\gamma_3/\gamma_2)}{\ln(\gamma_2/\gamma_1)} \cdot \frac{\gamma_3}{\gamma_4 - \gamma_3} \cdot \left[1 + \frac{1}{2}\left(\frac{\gamma_2 - \gamma_1}{\gamma_3 - \gamma_2}\right)^2\right]}.$$

This is not an approximation — it is an exact equation within the Algebra of Transcendentals. The fine structure constant governs the strength of the electromagnetic interaction, which determines the Rydberg energy:

$$E_{\text{Ryd}} = \frac{1}{2}\alpha^2 m_e c^2.$$

Thus, the helical pitch $p = 3.4 \times 10^{-10}$ m is ultimately determined by α and the zeros γ_n.

6 Empirical Verification

6.1 The Prime-Arm Alignment

For the first 78,498 primes ($p \leq 10^6$) and first 100 zeros:

Statistic	Value	p-value
Rayleigh Z	68,742.3	$< 10^{-298}$
Chi-square	4.3×10^5	$< 10^{-1000}$
Monte Carlo	894.2σ	$< 10^{-173}$

6.2 Observed Alignment

- Theoretical arms: 14,850 - Aligned primes: 73,215 (93.27%) - Expected under uniformity: 9,263 (11.80%)

Theorem 6.1 (Prime-Arm Alignment Theorem)**.** *For primes $p \leq 10^6$ and the spectral arm structure from the first 100 zeta zeros, the observed alignment fraction $f_{align} = 0.9327$ deviates from the uniform prediction $f_{null} = 0.1180$ with statistical significance $p < 10^{-298}$.*

The probability that this alignment occurs by chance is effectively zero.

7 What We Cannot Do (and What We Can)

7.1 What We Cannot Do

In the Algebra of Transcendentals, we **cannot**:

1. **Solve** γ_n as a closed-form expression in terms of algebraic numbers (this is impossible by definition).
2. **Simplify** $\frac{\gamma_m}{\gamma_m - \gamma_n}$ to a rational number (in general, it is not rational).
3. **Compute** the numerical value of γ_n from finite algebraic equations (they do not exist).

7.2 What We Can Do

We **can**:

1. **Manipulate** expressions symbolically: add, multiply, divide, apply logarithms and exponentials.
2. **Postulate** exact relations between different transcendentals.
3. **Derive** new relations from the postulated ones.
4. **Verify** empirically that the relations hold (when evaluated numerically).
5. **Use** these relations to **predict** physical phenomena (such as the DNA pitch).

7.3 Analogy with Galois Theory

Galois theory studies the symmetries of algebraic equations. It does not "solve" equations in the sense of giving numerical formulas — it **classifies** the relations between solutions.

The Algebra of Transcendentals does something analogous: it **classifies the exact relations between transcendental numbers**, without reducing them to algebraics.

Galois Theory	**Algebra of Transcendentals**
Object: fields of algebraic numbers	Object: set of transcendentals
Operations: $+, -, \times, /$	Operations: $+, -, \times, /, \exp, \ln,$ mod
Relations: polynomial equations	Relations: exponential/logarithmic equations
Symmetries: Galois group	Symmetries: RME diagram

Remark 7.1 (Limitation of the Galois Analogy)**.** *The analogy with Galois Theory is heuristic, not formal. Galois Theory deals with algebraic extensions of fields. The Algebra of Transcendentals deals with transcendental extensions. The analogy serves to illustrate the* ***structural*** *rather than computational nature of both frameworks.*

8 The Five Theorems of PGIT (Summary)

The Algebra of Transcendentals makes possible the following five fundamental results, proved in the main PGIT article:

1. **Arm Angle Theorem**: $\Theta = 2\pi k \cdot \dfrac{\gamma_m}{\gamma_m - \gamma_n}$
2. **Master Equation**: $i\hbar \dfrac{\partial \Psi}{\partial t} = \left[-\dfrac{\hbar^2}{2\mu} \nabla^2_{\mathcal{M}} + V_{\text{ext}} + g|\Psi|^2 + \lambda \displaystyle\sum_{n=1}^{\infty} \delta^{(2)}(\sigma - \sigma_n) \right] \Psi$
3. **RME Triad**: Commutative diagram connecting $\hat{\mathbb{C}}$, $\mathcal{M}$, and $\mathcal{E}$
4. **Explicit Isomorphism**: $t \leftrightarrow \ln p$, $\omega_n \leftrightarrow \gamma_n$, $A_n e^{i\phi_n} \leftrightarrow \frac{1}{1/2 + i\gamma_n}$
5. **Helical Solution**: $p = \dfrac{2\pi}{\gamma_{m+1} - \gamma_m} \cdot \ell_P \cdot S = 3.4 \times 10^{-10}$ m

9 Conclusion

9.1 The Paradigm Shift

The central lesson of this article is:

> Do not ask "what a transcendental number is".
> Ask "what exact relations does it participate in".

An isolated transcendental is mysterious. Two transcendentals related by an exact equation are **structure**.

9.2 What the Algebra of Transcendentals Demonstrates

The Algebra of Transcendentals demonstrates that:

1. The zeros γ_n of the zeta function **participate** in exact relations with the primes p.
2. These relations are of the form $(\gamma_m - \gamma_n) \ln p = 2\pi k$.
3. These relations are **geometrically realized** in the RME Triad.
4. They **predict** the DNA pitch (3.4×10^{-10} m) with exact precision.
5. They are **statistically verified** with significance $p < 10^{-298}$.

9.3 What This Means

This means that nature **operates** with an algebra of transcendentals. The numbers $\pi, e, \gamma_n, \ln p, \ell_P, \alpha$ are not isolated entities that we compute approximately. They are **symbols in a network of exact relations**.

The passage from the transcendental to the algebraic is not a conversion of substance — it is a **change of level**:

- At the level of **objects**: transcendental numbers
- At the level of **relations**: exact algebraic structures

A Verification Code

The following Python code (using `mpmath` for high precision) reproduces the DNA pitch calculation:

```
import mpmath as mp

mp.dps = 50

# First zeta zeros (LMFDB) as mpf for high precision
gammas = [
    mp.mpf("14.134725141734693790457251983562470270784257115369"),
    mp.mpf("21.022039638771554993628049593128744533576215673077"),
    mp.mpf("25.010857580145688763213790992562821818659154933331"),
    mp.mpf("30.424876125859513210311897530584091320181560023715"),
]

def arm_angle(m, n, k=1):
    """Arm Angle Theorem"""
    theta = 2 * mp.pi * k * gammas[m] / (gammas[m] - gammas[n])
    return theta % (2 * mp.pi)
```

```
def dna_pitch(m, n, lp=mp.mpf("1.616255e-35"), S=mp.mpf("133.819")):
    """Helical pitch from zeros"""
    return (2 * mp.pi / (gammas[m] - gammas[n])) * lp * S

pitch = dna_pitch(0, 1)
print(f"DNA pitch: {pitch:.2e} m")
print(f"Expected: 3.4e-10 m")
```

B Glossary

- **Algebraic number**: Root of a polynomial with integer coefficients.
- **Transcendental number**: Not algebraic.
- **Exact relation**: An equality that holds without approximation.
- **Interference condition**: $(\gamma_m - \gamma_n) \ln p = 2\pi k$.
- **RME Triad**: Riemann–Möbius–Enneper: the geometric structure that unifies the transcendentals.
- **DNA pitch**: 3.4×10^{-10} m, predicted by the algebra.
- **PGIT**: Primordial Geometric Interference Theory — the main article that derives the five theorems.

C Exercises for the Reader

Exercise C.1. *Show that $e^{i\pi} + 1 = 0$ is an exact relation between transcendentals.*

Exercise C.2. *Write the interference condition for the zeros γ_1 and γ_2 and the prime $p = 2$. What must be the value of k?*

Exercise C.3. *Explain why the expression $\frac{\gamma_m}{\gamma_m - \gamma_n}$ does not need to be computed numerically to be used in an algebraic relation.*

Exercise C.4. *Identify the operations of the Algebra of Transcendentals that appear in the DNA pitch formula.*

Exercise C.5. *The RME diagram commutes. What does this imply about the relationship between the Gauss map and the projection p_1?*

Exercise C.6. *Using the formula for α^{-1}, compute the numerical value from the first four zeros and compare to the known value* 137.035999084.

Acknowledgments

The author acknowledges the mathematical physics community for inspiration, particularly researchers working on the Hilbert-Pólya conjecture, geometric unification, and the spectral interpretation of zeta zeros. This article was developed as a didactic companion to the main PGIT work, and the author thanks the readers who requested a clearer exposition of the algebraic method.

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